CLAIMS

What is claimed is:

1. (currently amended)A Machine for Production of Granular Silicon comprising:

a heating section located below a reacting section; where said heating section comprises one or more tubes heated by one or more heaters

a mechanism that pulses silicon granules back and forth between the heating and reacting sections wherein the mechanism includes at least one separate injection means for injecting non silicon containing gases into the heating section ;

separate injection means for injecting silicon containing gases into the reacting section//:// ~~at least one separate injection means for injecting non silicon containing gases~~ and

a heating means to heat the non silicon containing gases above a reaction temperature .

2. (currently amended) A machine of claim 1 further including at least one additional stage connected above the reacting section and containing a second reacting section, a heating means ,and one or more gas injection means. ~~where there are multiple stages; a 1st stage comprising a heater section, a reaction section, a granule pulsing mechanism, a separate gas injection means for injecting silicon containing gases, a separate injection means for injecting non silicon containing gases and a heating means to heat the non silicon containing~~

~~gases above a reaction temperature and at least one additional stage comprising at least a heater section, a reaction section and a gas injection means.~~

3. (currently amended) A machine of claim 1 further comprising a means for recovering ~~the recovery of~~ heat from the granules by direct contact with a high purity gas, which has carbon and oxygen containing contaminants below 1 ppmv, parts per million by volume, ~~ppmwt and preferably below 10ppbwt~~ and which can be selected either from a ~~1st~~first group consisting of hydrogen, helium, argon, nitrogen and mixtures thereof, or from a ~~2~~ndsecond group consisting of helium, argon, nitrogen, silicon tetrachloride, ~~and~~ silicon tetrabromide and mixtures thereof. ~~but not mixtures of the 2nd group and hydrogen.~~

4. (currently amended) A machine of claim 1 further comprising a heat exchanger in which one or more containment means for the silicon containing gases are heated by hot liquid or condensing vapor maintained within a temperature range which cannot cause decomposition of the gases; which temperature range is ~~typically between~~ about 200-400°C ~~but more particularly between 300- 360°C~~.

5. (currently amended) A machine of claim 1 further comprising a sieving device, operated either continuously or in batches, by which the silicon granules are sieved using one or more sieves manufactured from non contaminating sieve material selected from the group consisting of single crystal silicon, polycrystalline silicon, silicon oxide, silicon nitride, silicon oxynitride, silicon carbide and mixtures thereof where the contaminants in the abradable surfaces will typically be below 1000 ppmwt ~~and preferably below 100 ppmwt~~.

6. (currently amended) A machine of claim 1 further comprising a feedstock recovery section; where hydrogen is injected in the heating section, a silicon containing gas selected from a ~~1~~st first group, consisting of trichlorosilane

dichlorosilane, tribromosilane, dibromosilane, triodosilane, diiodosilane and mixtures thereof is injected via the separate injection means for silicon containing gas in the reacting section and a silicon tetrahalide selected from a 2nd second group, consisting of silicon tetrachloride, silicon tetrabromide and silicon tetraiodide is injected after the reactor section, mixed with the reactor effluent then quenched at an optimal temperature to recover hydrohalosilanes selected from the ~~aforesaid 1st~~ first group, residual silicon tetrahalides selected from the 2nd second group and hydrogen.

7. (previously presented) A machine of claim 1 further comprising one or more cooled joints between external equipment and the reactor which transmit hot gases or solids and which are cooled using, one or more, microchannels positioned to primarily cool the immediate area around the connection to the reactor and/or the seal area of the connection to the external equipment.

8. (currently amended) A machine of claim 1 further comprising an external flow control means for controlling flow to each of ~~each~~ said injection means, selected from a group consisting of: a means for ~~either~~ direct ~~with~~ flow control of each said injection means ~~done independently, or indirect by means of~~ a means of indirect flow control by a flow distribution device or a combination of the two where some of the said injection means are ganged in groups.

9. (previously presented) A machine of claim 1 where the instantaneous flow of gases into the reactor through one or more of the injection means is varied periodically and/or the distribution of flow between said injection means is adjusted to control the generation of new particles without changing the total flow averaged over 1 minute.

10. (currently amended) A machine of claim 4 where the location of the one or more flow control means for the ~~flow of~~ silicon containing gas ~~to one more~~

of ~~the separate injection means for silicon containing gas is controlled~~ is upstream of ~~before~~ the heat exchanger ~~and an even more preferred option where multiple separate flows containment means of the silicon containing gas are in the same heat exchanger~~.

11. (previously presented) A machine of claim 2, where high purity hydrogen is used for the non silicon containing gas to the first stage and silane is injected via the separate injection means for silicon containing gas in all the stages.

12. (currently amended) A machine of claim 2, where; high purity hydrogen is injected in the first and subsequent stages, a silicon containing gas selected from a ~~1st~~ first group consisting of trichlorosilane, dichlorosilane, tribromosilane, dibromosilane, triodosilane, diiodosilane and mixtures thereof is injected via the separate injection means for silicon containing gas in the ~~1st~~first stage and further comprising a final feedstock recovery system where a silicon tetrahalide selected from a ~~2~~2nd second group consisting of silicon tetrachloride, silicon tetrabromide and silicon tetraiodide is injected, mixed with the reactor effluent then quenched at an optimal temperature to recover gases from the prior ~~1st~~first group, residual silicon tetrahalides from the prior ~~2~~2nd second group and hydrogen.

13. (currently amended) A machine of claim 1 where the heating section is of smaller diameter than the reacting section above it and connected by a tapered section, angle of said tapered section to be between 10 and 80 degrees from the vertical ~~and preferably between 30-60 degrees from the vertical~~.

14. (currently amended) A machine of claim 1 where the heaters used in the heating sections are selected from the group consisting of resistance heaters.

inductive RF heaters, microwave heaters, lamp heaters or lasers ~~but are preferably resistance heaters~~.

15. (previously presented) A machine of claim 6 where a cyclone is used after the injection of the silicon tetrahalide to remove silicon dust and to provide residence time for the mixing and reaction of the silicon tetrahalide with ~~from~~ the reactor effluent and the silicon dust to improve the recovery of the said silicon hydrohalosilanes and tetrahalides.

16. (currently amended) A machine of claim 1 further including a means of supplying a silicon etching gas ~~may be~~ which is injected through one or more of the injection means for the purpose of etching wall deposits from all or part of the reactor, where the gas is selected from the group consisting of chlorine, bromine, iodine, hydrogen chloride, hydrogen bromide, hydrogen iodide, a mixture of hydrogen and silicon tetrachloride, a mixture of hydrogen and silicon tetrabromide, a mixture of hydrogen and silicon tetraiodide and mixtures thereof.

17. (currently amended) A machine of claim 1 where the reactor is supported upon a weigh cell, capable of both weighing the reactor and its contents and of measuring the intermittent force exerted by the pulsing granules and where the connections to and from the reactor are flexible enough to allow the ~~slight deflection~~ movement required by the weigh cell, ~~said deflection to be less than 1mm and preferably less than 0.5mm,~~ and the thermal expansion of the reactor relative to the support structure, said movement ~~thermal expansion~~ to be less than 1" (25mm) ~~and preferably less than 1/4" (6mm)~~.

18. (previously presented) A machine of claim 1 where all or a portion of the non silicon containing gases are heated to a temperature below the reaction temperature outside the heating section then heated to a temperature above the

reaction temperature inside the heating section prior to entry to the reacting ~~section.~~

19. (currently amended) A machine of claim 2 where at least one of the ~~second and subsequent~~ the at least one additional stage ~~heating sections~~ contains some residual silicon dust and/or silicon containing gases ~~from the first stage reacting section that form a wall deposit.~~

20. (canceled)

dichlorosilane, tribromosilane, dibromosilane, triodosilane, diiodosilane and mixtures thereof is injected via the separate injection means for silicon containing gas in the reacting section and a silicon tetrahalide selected from a ~~2nd~~ second group, consisting of silicon tetrachloride, silicon tetrabromide and silicon tetraiodide is injected after the reactor section, mixed with the reactor effluent then quenched at an optimal temperature to recover hydrohalosilanes selected from the ~~aforesaid 1st~~ first group, residual silicon tetrahalides selected from the ~~2nd~~ second group and hydrogen.

7. (previously presented) A machine of claim 1 further comprising one or more cooled joints between external equipment and the reactor which transmit hot gases or solids and which are cooled using, one or more, microchannels positioned to primarily cool the immediate area around the connection to the reactor and/or the seal area of the connection to the external equipment.

8. (currently amended) A machine of claim 1 further comprising an external flow control means for controlling flow to each of ~~each~~ said injection means, selected from a group consisting of: a means for ~~either~~ direct ~~with~~ flow control of each said injection means ~~done independently, or indirect by means of~~ a means of indirect flow control by a flow distribution device or a combination of the two where some of the said injection means are ganged in groups.

9. (previously presented) A machine of claim 1 where the instantaneous flow of gases into the reactor through one or more of the injection means is varied periodically and/or the distribution of flow between said injection means is adjusted to control the generation of new particles without changing the total flow averaged over 1 minute.

10. (currently amended) A machine of claim 4 where the location of the one or more flow control means for the ~~flowof~~ silicon containing gas ~~to one more~~

of the separate injection means for silicon containing gas is controlled is upstream of before the heat exchanger and an even more preferred option where multiple separate flows containment means of the silicon containing gas are in the same heat exchanger.

11. (previously presented) A machine of claim 2, where high purity hydrogen is used for the non silicon containing gas to the first stage and silane is injected via the separate injection means for silicon containing gas in all the stages.

12. (currently amended) A machine of claim 2, where; high purity hydrogen is injected in the first and subsequent stages, a silicon containing gas selected from a 1st first group consisting of trichlorosilane, dichlorosilane, tribromosilane, dibromosilane, triodosilane, diiodosilane and mixtures thereof is injected via the separate injection means for silicon containing gas in the 1st first stage and further comprising a final feedstock recovery system where a silicon tetrahalide selected from a 2nd second group consisting of silicon tetrachloride, silicon tetrabromide and silicon tetraiodide is injected, mixed with the reactor effluent then quenched at an optimal temperature to recover gases from the prior 1st first group, residual silicon tetrahalides from the prior 2nd second group and hydrogen.

13. (currently amended) A machine of claim 1 where the heating section is of smaller diameter than the reacting section above it and connected by a tapered section, angle of said tapered section to be between 10 and 80 degrees from the vertical and preferably between 30-60 degrees from the vertical.

14. (currently amended) A machine of claim 1 where the heaters used in the heating sections are selected from the group consisting of resistance heaters,

inductive RF heaters, microwave heaters, lamp heaters or lasers ~~but are preferably resistance heaters~~.

15. (previously presented) A machine of claim 6 where a cyclone is used after the injection of the silicon tetrahalide to remove silicon dust and to provide residence time for the mixing and reaction of the silicon tetrahalide with ~~from~~ the reactor effluent and the silicon dust to improve the recovery of the said silicon hydrohalosilanes and tetrahalides.

16. (currently amended) A machine of claim 1 further including a means of supplying a silicon etching gas ~~may be~~ which is injected through one or more of the injection means for the purpose of etching wall deposits from all or part of the reactor, where the gas is selected from the group consisting of chlorine, bromine, iodine, hydrogen chloride, hydrogen bromide, hydrogen iodide, a mixture of hydrogen and silicon tetrachloride, a mixture of hydrogen and silicon tetrabromide, a mixture of hydrogen and silicon tetraiodide and mixtures thereof.

17. (currently amended) A machine of claim 1 where the reactor is supported upon a weigh cell, capable of both weighing the reactor and its contents and of measuring the intermittent force exerted by the pulsing granules and where the connections to and from the reactor are flexible enough to allow the ~~slight deflection~~ movement required by the weigh cell, ~~said deflection to be less than 1mm and preferably less than 0.5mm,~~ and the thermal expansion of the reactor relative to the support structure, said movement ~~thermal expansion~~ to be less than 1" (25mm) ~~and preferably less than 1/4" (6mm)~~.

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reaction temperature inside the heating section prior to entry to the reacting section.

19. (currently amended) A machine of claim 2 where at least one of the ~~second and subsequent~~ the at least one additional stage ~~heating sections~~ contains some residual silicon dust and/or silicon containing gases ~~from the first stage reacting section~~ that form a wall deposit.

20. (canceled)

A Machine for Production of Granular Silicon

<u>U.S. Patent Application of:</u>

Stephen Michael Lord

Related Applications

Application Number 09/507,154

Filing Date 02/18/2000

GRP Art Unit 1754

Inventor: Stephen M. Lord

Title: Method for Improving the Efficiency of A Silicon Purification Process

Application Number 09/589563

Filing Date 06/06/00

GRP Art Unit 1754

Inventor: Stephen M. Lord

Title : Methods for Heating a Fluidized Bed Silicon Deposition Apparatus